InLCA: Selected Papers

# Land Use and Biodiversity Indicators for Life Cycle Impact Assessment

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**Abstract**

**Background.** The primary purpose of environmental assessment is to protect biological systems. Data collected over the last several decades indicates that the greatest impacts on biological resources derive from physical changes in land use. However, to date there is no consensus on indicators of land use that could be applicable worldwide at all scales. This has hampered the assessment of land use in the context of LCA.
**Objectives.** The Institute for Environmental Research and Education and its partner Defenders of Wildlife have begun an effort to develop the necessary consensus.
**Methods.** In July 2000, they held a workshop attended by a diverse group of interested parties and experts to develop a preliminary list of life cycle indicators for land use impacts
**Results.** Their preliminary list of impact indicators includes: protection of priority habitats/species; soil characteristics: soil health; proximity to & protection of high priority vegetative communities; interface between water and terrestrial habitats/buffer zones; assimilative capacity of water and land; hydrological function; percent coverage of invasive species within protected areas; road density; percent native-dominated vegetation; restoration of native vegetation; adoption of Best Management Practices linked to biodiversity objectives; distribution (patchiness; evenness, etc.); and connectivity of native habitat.
**Conclusion.** The list of indicators conforms well to other efforts in developing indicators. There appears to be convergence among experts in the field and in related fields on the appropriate things to measure.
**Future Prospects.** These indicators are currently being tested in the United States. Further workshops and testing is planned towards developing internationally recognized indicators for land use.

**Keywords:** Biodiversity; InLCA; ISO 14042; Land Use; Land Use Indicators; Life Cycle Assessment (LCA); LCA; LCIA; Life Cycle Impact Assessment (LCIA)

## 1 Introduction and Background

Consider for a moment the underlying purpose for which all environmental assessments are performed. Some possible reasons include: to gain economic benefit; to reduce life cycle costs of products; to achieve reduced liability; for market advantage; to improve management systems; for public policy. All of these may be the drivers behind the decision to perform an environmental assessment. However, when one strips away all immediate motivations, the underlying reason all environmental assessments are performed is that we value the living resources of the planet. Mining wastes are irrelevant if there are no ecosystems that may be damaged by them. We are not concerned about the environmental impacts of satellites falling into the sun, but are very concerned that they may fall to the earth. Regardless of all immediate reasons to perform environmental assessments, the root cause of this work is concern for biological systems.

Despite the value we place on living systems, we have been extremely effective as a species at destroying them. Over the last several decades, scientists and conservationists have documented alarming declines in biological systems worldwide as a result of human activities. A recent compilation of these declines can be found in a report by the World Resources Institute (1999), where it was noted that

- Half of the world's wetlands were lost last century.
- Logging and conversion have shrunk the world's forests by as much as half.
- Some 9 percent of the world's tree species are at risk of extinction; tropical deforestation may exceed 130,000 square kilometers per year.
- Nearly 70 percent of the world's major marine fish stocks are overfished or are being fished at their biological limit.
- Soil degradation has affected two-thirds of the world's agricultural lands in the last 50 years.
- Some 30 percent of the world's original forests have been converted to agriculture.
- Dams, diversions or canals fragment almost 60 percent of the world's largest rivers.
- Twenty percent of the world's freshwater fish are extinct, threatened or endangered.

An interesting characteristic of all these findings is that they are all related to physical changes in land use: agricultural activities, installation of dams, urbanization and biological resource extraction practices. In contrast, with a few notable exceptions, (Pré Consultants 1999, Norberg et al. 1996) very few life cycle assessments even consider the changes of land use in evaluating the impacts of products and services. This lack has been noted by Andersson (2000), and SETAC Europe has begun to evaluate land use as an impact category, although discussions to date have centered more around the issue of system boundaries and other inventory issues rather than the development of impact indicators.

Fortunately, a great deal of work has been done in the field of ecology, agriculture and conservation by many groups to document and evaluate the effects of land use on biodiversity and sustainability (Defenders of Wildlife 1998, Heinz Center 1999). Of particular interest is the work funded by the World Bank which brought together experts from around the world to discuss the current state and potential research in the area of Land Quality Indicators. That group was evaluating sustainable land use in all three aspects of sustainability: environmental, economic and social. Under the rubric of environmental sustainability, they identified several indicators that could be useful in evaluating the impacts of land use (Dumanski and Pieri 2000). They include: nutrient effects, both depletion in soils and excess use leading to pollution effects downstream; soil quality (measured by soil organic matter); natural habitat loss; habitat fragmentation; species loss even when natural habitat is intact (related to pollution); decline of biodiversity of crop species on farms; decline of biodiversity within crop species (measured by adoption of modern varieties).

In the United States, one can envision the degradation of the environment yielding very high impacts when evaluated using these indicators. For example, maize (corn) is the crop that uses the most agricultural land in the United States. Some counties have more than half their area devoted to the production of maize. The average maize field is cultivated through intensive tillage, and high use of inorganic fertilizers (especially anhydrous ammonia), herbicides and pesticides. The use of monoculture of single cultivars is common. These practices result in a loss of soil organic carbon (which is typically one percent or less in these soils) and high runoff of nitrogen and particulate matter to streams. Little of the natural ecosystem remains. Cornfields provide little ecosystem function either, even though they do provide some food source and cover to game birds. The majority of the corn grown is used as feed for animals raised in confinement, and the manure management for these confinement systems is a major source of nutrient pollution to coastal waters.

Efforts to identify ecosystem health indicators have been made by many conservation groups, notably the Defenders of Wildlife, the Nature Conservancy and the World Wildlife Fund. To date, however, there is no consensus on indicators of land use either in the US or worldwide. This report describes the beginnings of an effort jointly sponsored by the Defenders of Wildlife and the Institute for Environmental Research and Education (IERE).

## 2 Workshop and Outcomes

In July of 2000, a workshop was convened in Washington D.C. to discuss the need for life cycle indicators for landuse/biodiversity. The attendees represented a diverse group of interests by representatives of environmental NGOs, the U.S. Government, university researchers and business. Interests ranged widely, but most of the participants had direct experience in developing or using indicators or standards for environmental performance. A list of attendees' organizations can be seen in Table 1. This workshop was envisioned as the first of several, beginning the dialog towards consensus. Future workshops should include international input.

**Table 1:** Attendees affiliations

| |
|---|
| Defenders of Wildlife |
| Heinz Center for Science, Economics and the Environment |
| Institute for Environmental Research and Education |
| Merck and Co. |
| National Resource Conservation Service |
| The Nature Conservancy |
| U.S. Congressional Research Center |
| U.S. Environmental Protection Agency |
| University of Iowa |
| US Department of Agriculture |
| USDA-Economic Resources |

The ultimate goal is to have indicators of land use/biodiversity that can be used anywhere in the world, and that could aggregate impacts in multiple locations, and that can be useful for life cycle assessment and other purposes. The goal of this workshop was to develop a relatively short list of preliminary indicators that met the following criteria. They should:

1. Refer to physical, not chemical disruptions of the land
2. Based on what was known of ecological principles, should correlate well with the actual impacts of land use on biodiversity
3. Be applicable anywhere in the world, in both urban and rural settings
4. Be applicable at all scales
5. Be relatively simple to measure and reproducible
6. Be relatively few in number
7. Aggregate across different landscapes
8. Be useful not only for LCA but for other purposes.

The attendees of the workshop came from very different backgrounds, and some time was spent discussing and clarifying concepts and the goal. However, there was clear consensus in the group that physical changes in land use are the single greatest sources of loss of biodiversity world wide, and that indicators that could be used to measure and reward landowners for preserving ecological values needed to be developed. Further, a clear consensus emerged about what types of indicators should be pursued, and ultimately a short list of indicators was developed for further testing.

There was a clear preference for measurement of the environmental state over environmental pressure indicators. However, it was recognized that pressure indicators are generally easier to obtain, and represent leading rather than trailing indicators. As a practical matter they may be the best option until better data becomes available.

One important characteristic of environmental indicators is how well they can be aggregated. It is important that the information that is gathered can be rolled up to higher levels to meet different needs. For example, although land use decisions are made on a field by field basis on farms, policy makers need to look at the aggregated land use over many scales: watershed, regional or national. In addition, one may wish to look at aggregation of land use decisions over time as well as space. Time trend analysis is one way to think about this, but also, the data sampled at different times should be comparable: randomized methodologies will sample different points at different times.

In addition, one may wish to aggregate different measures of land use to achieve a single indicator of impacts. For example, one might want to aggregate landuse decisions on farms with use decision for forests. One participant likened this to adding up apples and oranges to get fruit. Very often, policy makers need to know the size of the total fruit basket, not the individual apples and oranges.

If we wish to have indicators of land use, they must provide useful guidance to decision-makers on actions that should be taken. In this context, the group discussed the issues of ecosystem integrity and scale. Ecologists have known for decades that the fragmentation of environments leads to the loss of species diversity. So the question arises: how large a piece of land must be preserved in order to preserve biodiversity values?

One attendee suggested that units of 25,000 acres (10,000 hectares) were appropriate units to evaluate, especially in a grasslands/prairie ecosystem. This size of planning unit permits management of mammals and birds. If at least 30% of the land is being managed for biodiversity values, then bird populations seem quite healthy, and further preservation does not yield further improvements. Another attendee noted that quite small units, on the order of one acre can be important for the preservation of amphibians and reptiles. There was general consensus that the appropriate planning size depends on the species one is interested in preserving and that progress can be made on all scales.

Possibly the most important issue of preserving systems integrity is access to open waters. The interface between water and land is important to all animals, and protecting this area may well be the best first step towards preserving wildlife.

There was also general recognition that the focus on animals was less useful than the focus on plants. Animals are entirely dependent on the primary production and the physical environment provided by plants, and being mobile, they have the opportunity to leave undesirable habitats. Animals are also often flexible with respect to the actual plants they associate with. For example, cornfields have replaced native grasses as a source of protective habitat and to a lesser extent, food for some birds. In a similar fashion, flooded rice fields provide habitat for migrating water birds. As a practical matter, the rooted nature of plants makes them much better subjects for sampling by remote sensing.

The group undertook a brainstorming effort to identify potentially useful indicators. After consolidation of similar ideas, the following list was developed.

- Protection of priority habitats/species
- Soil characteristics: soil health
- Proximity to & protection of high priority vegetative communities
- Interface between water and terrestrial habitats/buffer zones
- Assimilative capacity of water and land; hydrological function
- Percent coverage of invasive species within protected areas
- Road density
- Percent native-dominated vegetation
- Restoration of native vegetation
- Adoption of Best Management Practices linked to biodiversity objectives
- Distribution (patchiness; evenness, etc.)
- Connectivity of native habitat

## 3 Summary, Conclusions and Future Work

The workshop brought together individuals with the background and interest necessary to begin the process of developing useful indicators for land use/biodiversity that can be used at all scales. These preliminary discussions identified several areas of concurrence that should be evaluated to measure the impacts of land use. Considering the diverse backgrounds of the individuals at this workshop, the convergence of thought towards a few indicators was very encouraging.

IERE will be testing these indicators in the field over the next year. IERE is working with farmers in the US to improve their overall environmental performance, using LCA as the measurement system. To evaluate land use decisions, IERE will be measuring the parameters described in Table 2, and will report back to the workshop group the results of that effort. Defenders of Wildlife will be undertaking similar efforts in urban areas (particularly in the Portland, Oregon area).

An interesting characteristic of these selected indicators is that they are all relatively easy to measure, and even the supporting information needed (e.g. maps of threatened and endangered species) are typically reasonably available. In addition, these indicators converge well with those proposed by Dumanski (2000), further supporting their validity on a global scale.

IERE's and Defenders of Wildlife's efforts need to be complemented by the efforts of others in different environments. While the primarily agricultural/prairie one that IERE is studying is an important one from the point of view of the landuse impacts of agricultural practice, other landscapes, such as urban and forest landscapes are equally important.

We anticipate that developing good indicators will take several years: these preliminary indicators are just a start. Par-

**Table 2:** Preliminary landuse/biodiversity indicators and measures

| Biodiversity Indicators | Proposed Measures |
|---|---|
| Protection of priority habitats/species | Area of habitat that is physically protected (i.e.; through fencing or other methods); habitat to be identified as including<br>• 100 feet (30 meters) each side of rivers<br>• Habitat of Threatened & Endangered species |
| Soil characteristics: soil health | Concentration of organic carbon in the soil |
| Proximity to & protection of high priority vegetative communities | Area of habitat set aside (not farmed) that is identified as 'high priority' in The Nature Conservancy vegetative maps |
| Interface between water and terrestrial habitats/buffer zones | Total linear space of aquatic habitat (i.e. river, lakeshore, etc) protected via physical means vs. total area managed |
| Assimilative capacity of water and land (TMDL process); hydrological function | Depletion of water resources (annual use versus recharge rate) |
| Percent coverage of invasive species (within protected areas) | For physically protected areas, density of non-native vegetation (area percent) |
| Road density | Units of road per square units ($km/km^2$) |
| Percent native-dominated vegetation | Area in native species dominated areas/total area managed |
| Restoration of native vegetation | Area newly returned (in last 12 months) to native habitat |
| Adoption of BMP s linked to biodiversity objectives | Number of Best Management Practices adopted |
| Distribution (patchiness; evenness, etc.) | Size of native-managed acres vs. total area managed<br>Size of native-managed acres vs. average field size |
| Connectivity of native habitat | On managed areas, percent of native-managed land units that has at least one adjacency to other native-managed land |

ticipation from our colleagues in other countries is essential in order to develop a global perspective. We therefore invite our colleagues worldwide to participate in our efforts. We are planning another workshop sometime in the Summer of 2001, to report out on our efforts and to continue the process of developing the necessary indicators.

There are important policy reasons for the development of LCA indicators of land use. Changes in land use are the primary source of losses of biodiversity world-wide. If we wish to perform LCAs with a "comprehensive list of impact categories" per ISO 14042, leaving out the issue of land use insures that we are avoiding a true evaluation of the environmental impacts of products and services. In no product area is this more clear than in agricultural products. In the United States, the federal government had developed an Environmentally Preferable Purchasing Program (EPP) for federal procurement that requires federal government purchasing agents to give preference to environmentally superior products. At the same time, the executive orders directing this program give default preference to bio-based products. Ignoring the land use impacts of bio-based products will lead to their preference even when it can be proved that they have immense impacts on the biosphere.

At the same time, it is possible to make agricultural use of land that actually protects the biosphere, through management to support ecosystem values. LCA indicators of land use will help producers by providing clear guidance for supporting ecosystem values and by providing a basis for ecolabels.

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